BELLCOMM, INC.
955 L'ENFANT PLAZA NORTH, S.W. WASHINGTON, D. C. 20024

B70 08035

SUBJECT: Space Ground Link Subsystem (SGLS) Characteristics - Case 900

DATE: August 18, 1970

FROM: J. H. Fox

ABSTRACT

North American Rockwell has proposed an S-Band communications system for its version of the Space Station/Space Base which uses the same frequency bands--1800 MHz up and 2200 to 2300 MHz down--as does the Space Ground Link Subsystem (SGLS) in use by the Air Force Satellite Control Facility (AFSCF). This memorandum describes some of the salient characteristics of the SGLS.

The SGLS is a modularized, integrated, coherent communications link which bears many similarities to the NASA Unified S-Band System (USBS). Both systems use a modification of the JPL Mark I System, both are coherent systems and there is similarity in services offered.

A major difference exist in the frequency bands of the up-links and in the subcarriers used in the down-links. The USBS up-link is 280 to 330 MHz higher than the SGLS frequency band. However, since the SGLS uses a larger down-link frequency mutliplier (256/205) than does the USBS (240/222) the SGLS down-link carrier band is wider and encompasses the USBS band. Thus, the SGLS ground equipment is capable of detecting, receiving, recording and processing USBS telemetry while the USBS ground equipment does not cover SGLS telemetry frequencies. Also, since each system uses a different uplink frequency spectrum a substantial change in concept and equipment would be required before one system could be used to command the other.

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MEMORANDUM FOR FILE

Introduction

North American Rockwell has proposed an S-Band communications system for its version of the Space Station/Space Base. The frequencies proposed--1800 MHz up and 2200 to 2300 MHz down--are those occupied by the Space Ground Link Subsystem (SGLS) in use by the Air Force Satellite Control Facility (AFSCF). This memorandum describes some of the salient characteristics of the SGLS.

Development History

The SGLS was developed by the AFSCF to meet the triple requirements of (1) vacating the VHF frequency spectrum by 1970, (2) accomodating an increasing spacecraft population with fixed resources by reducing ground station turn-around times between spacecraft contacts and by increasing data transmission rates and (3) improving tracking accuracy.

Design of the system took full advantage of the then state of the art in tracking, telemetry and command components with particular attention given to the technology developed for the NASA Unified S-Band System (USBS). Development begain in 1964 and culminated in two successful demonstration flights in late 1966. Since all test objectives were met, the remaining two test flights were cancelled and the system was declared operational at that time.

Characteristics

General

The SGLS is an integrated S-band tracking, telemetry, and command subsystem. It is integrated in the sense that all the downlink functions of spacecraft acquisition, tracking and data transmission including voice are on a single RF carrier in the 2.2-2.3 GHz band for transmission to a single ground antenna. In like fashion, all uplink data are multiplexed onto a single carrier in the 1.76-1.84 GHz band for transmission to the spacecraft receiver.

Design requirements specified that:

(1) The command up-link must occupy the upper portion of the 1700-1850 MHz band and that a minimum separation of 2.5% must be provided between the SGLS up-link band and the NASA 1700-1710 MHz receive band to preclude interference.

(2) The selected coherent frequency ratio must allow operation over the entire telemetry down-link band of 2200 to 2300 MHz without violating the command up-link allocation.

(3) The frequency ratio selected must be compatible with a possible future extension of SGLS to permit operation on USBS frequencies.

Ground Equipment

The SGLS ground station has semiautomatic configuration control and diagnostic test capabilities. Transmission of command signals is via any one of ten crystal controlled preset frequencies in the range of 1762-1842 MHz (Fig. 1) at a controllable power input of from zero to 10KW. The uplink carrier frequency is acquired by the SGLS receiver in the spacecraft, multiplied by a factor of 256/205 and retransmitted as the downlink carrier frequency. This coherency feature enables doppler frequency changes to be detected thereby yielding range rate. Range is determined by measuring the phase shift of a pseudo-random noise (PRN) code. Angular position is determined by the apparent angle of arrival of the spacecraft signal. Telemetry (PCM) capabilities are given in Table I.

In the AFSCF the SGLS ground station is used with either of the two standard system antennas (14' dia and 60 ' dia) in either a con-scan or monopulse tracking mode. Simultaneous transmission and reception from a single antenna is used. The major elements of the ground receiver are: Parametric pre-amplifiers, reference receiver, angle tracking receiver, baseband separation unit, wideband telemetry demodulator, doppler frequency converter and ranging interface assembly. Range measurements are unambiguous to either 5000 or 400,000 nautical miles depending on which PRN code length is selected. The ranging equipment is a modification of the JPL Mark I System used in the Deep Space Network (DSN). The main receiver is functionally similar to the Apollo USBS System with the basic difference that the design was modified to provide operation throughout the 2200-2300 MHz frequency range. The System was designed to measure range rates of up to 40,000 fps with a 1σ error of 0.2 fps.

Figure 2 is a block diagram of the main elements of the spacecraft and ground system. The ground-to-spacecraft carrier is generated in the ground transmitter and, after modulation by command, voice and ranging data, passes through the diplexer to the ground antenna for radiation to the spacecraft antenna.

Spacecraft Equipment

The up-link carrier is received by the spacecraft antenna, passes through the phase-lock receiver and is demodulated. The data are then routed to the requisite components such as the command decoder.

The receiver also generates a coherent drive signal for Transmitter No. 1 at a rational fraction of 8/205 times the received frequency. This signal is then multiplied by 32 in the transmitter to form the spacecraft-to-ground Carrier No. 1 which is thereby coherently related to the up-link carrier by the rational multiplier 256/205. This down-link carrier is modulated by medium bit-rate PCM, voice, PAM/FM, FM/FM and ranging signals. It is then passed through the multiplexer to the spacecraft antenna for transmission to the ground. Transmitter No. 2 generates a second carrier 5 MHz in frequency below the first which, after modulation by the high bit-rate PCM (128-1024 kbps), is passed through the multiplexer to the common antenna.

The major components of the flight equipment were designed in modular form so that each space program could select, off-the-shelf, those it needed and not be forced to pay weight, power and cost penalties. A typical configuration weighs 26 pounds, occupies 900 cubic inches and consumes 57 watts power with a 28V input. Early in the development program it became evident that the design goal of complete standardization and modularity was unrealistic and needlessly restricted spacecraft design and flexibility. As a result, a compromise was reached between certain spacecraft programs and the ground system wherein an "Ether Interface" was defined. Each flight program could then modify or configure its spacecraft communications subsystem as it wished and as long as the subsystem was compatible with the "Ether Interface" all of the SGLS ground equipment capabilities would be available for support.

Reliability of the Spacecraft Equipment

Reliability calculations early in the development program indicated a MTBF of 7000 hours for the flight test configuration. Critical components are the command decoder and the digital telemetry unit (DTU) which had 33,800 and 38,650 hours MTBF respectively. The MTBF of the command decoder was computed on the basis that all 39 output drivers must be available at all times. If less than 39 commands are required this MTBF rate would be conservative. The DTU MTBF calculations were based on an allowable 5% loss of digital data and a 5% loss of analog data. Larger tolerances would improve the MTBF rate significantly.

Comparison of SGLS and USBS

The SGLS as used by the AFSCF and the USBS as used by NASA are similar in many respects. Both use a modification of the JPL Mark I ranging system (Figure 3), both are coherent systems in that the down-link RF carrier is a multiple of the up-link carrier frequency and, as shown in Table II, there is similarity in services offered. Differences exist: the high rate PCM (above 128 kbps) is unique to the SGLS; also, there is a major difference in the frequency bands of the up-links and in the subcarriers used in the down-links. The USBS up-link is 280 to 330 MHz higher than the SGLS frequency band. However, since the SGLS uses a larger multiplier (256/205) than does the USBS (240/221) the SGLS down-link carrier band is wider and encompasses the USBS band. Thus, the SGLS ground equipment is capable of detecting, receiving, recording, and processing USBS telemetry but the reverse is not true.

The SGLS PRN ranging and voice (single channel) are both compatible with USBS. This compatibility goal was the primary reason for the selection of the 30 KHz subcarrier for voice.

A significant difference exists in the command up-link frequency spectrum used. Here, compatibility with the USBS does not exist and to establish compatibility such that one system could command the other a substantial change in concept and equipment would be required.

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TABLE I

SGLS Digital Telemetry Unit Capabilities

Format	Variable word length 4 to 64 bits in increments of 4 bits. Nonreturn to zero (NRZ) PCM
Inputs	(1) Analog: 4 or 8 bit analog-to-digital conversion accuracy (2) Digital: In 4 bit increments (3) Discretes
Analog input level	0 to +5.0 V
Frame length	1024 bits expandable to 2048 bits
Words in main frame	256 maximum; expandable to 512 for 2048 bit frame
Bit rate	15 rates from 8 bps to 1024 kbps with maximum of two rates per unit switched by command
Subcommutation	8 subframes (128 8 bit words maximum)
Subframe length	16, 32, 64 and/or 128 words, each subframe
Supercommutation	Unrestricted

TABLE II

Comparison of SGLS and USBS Characteristics

		SGLS	USBS
UPLINK			
	RF Carriers	1.76-1.84 GHz	2.09-2.12 GHz
	Subcarriers	30, 65, 76, 95 KHz and 1.25 MHz	30, 70 KHz
	Services	Voice, commands, PRN ranging, and Analog	Voice, commands, and PRN ranging.
DOWN-LINK			
	RF Carriers	2.2-2.3 GHz	2.27-2.3 GHz
	Subcarriers	1.024, 1.25 and 1.7 MHz	.512, 1.024, 1.25 MHz plus additional telemetry sub-carriers intended for future science missions.
	Services	Voice, PRN ranging, range rate, Analog, FM/FM, PAM/FM and PCM	Voice, PRN ranging, range rate, PAM/FM/FM, FM/FM, PCM and TV

SELECTED REFERENCES

1. Proceedings of the Apollo Unified S-Band Technical Conference, Goddard Space Flight Center, July 14-15, 1965. NASA SP-87.

2. Final Design Report, Space Ground Link Subsystem, Volume 1, TRW Systems, 1 February 1967.

3. Space-Ground Link Subsystem Development and Implementation in the Air Force Satellite Control Facility, Colonel James W. Heyroth, Telemetry Journal, April/May 1969, pp. 32-40.

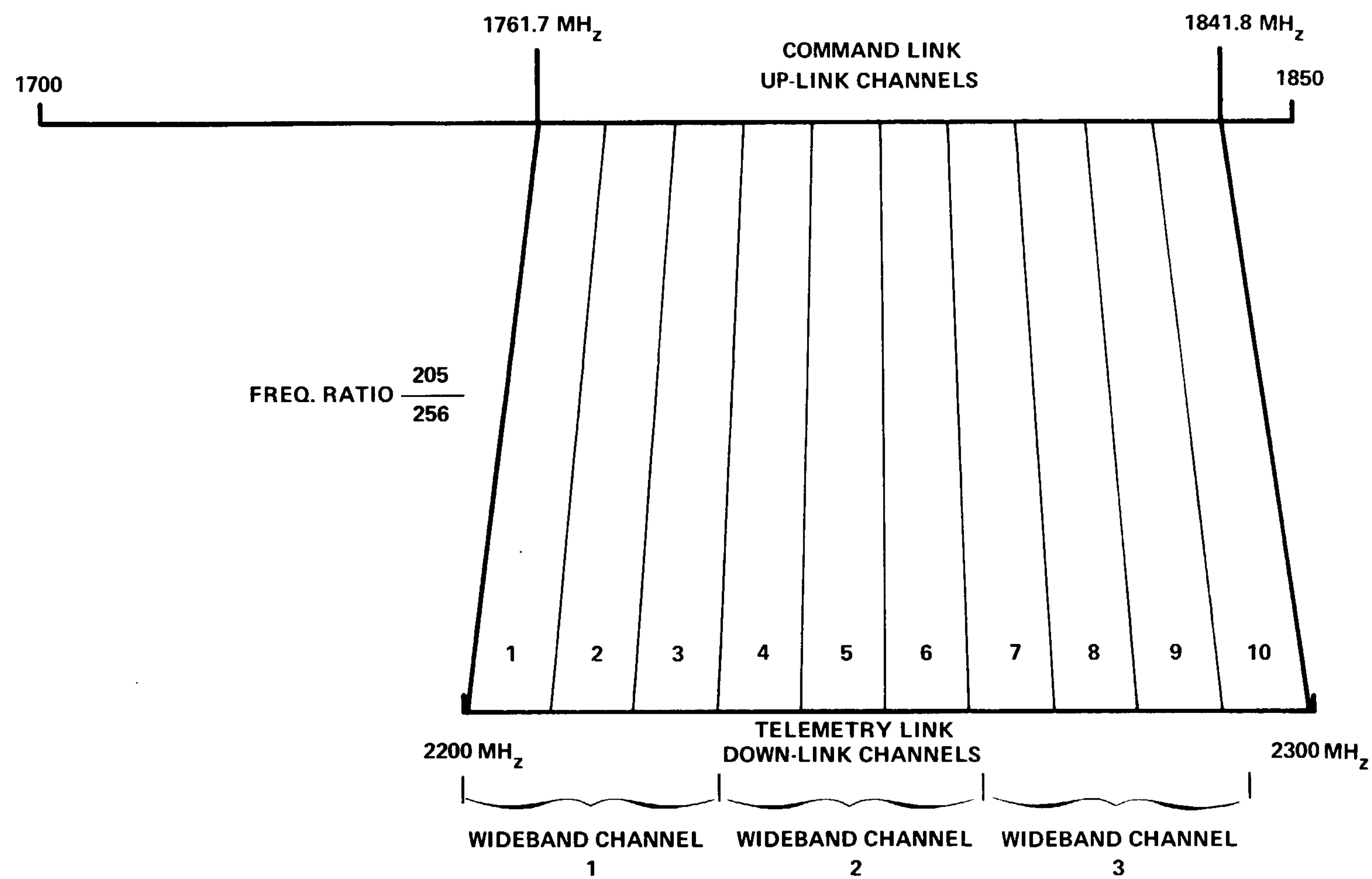

FIGURE 1 - SGLS SPECTRUM OCCUPANCY

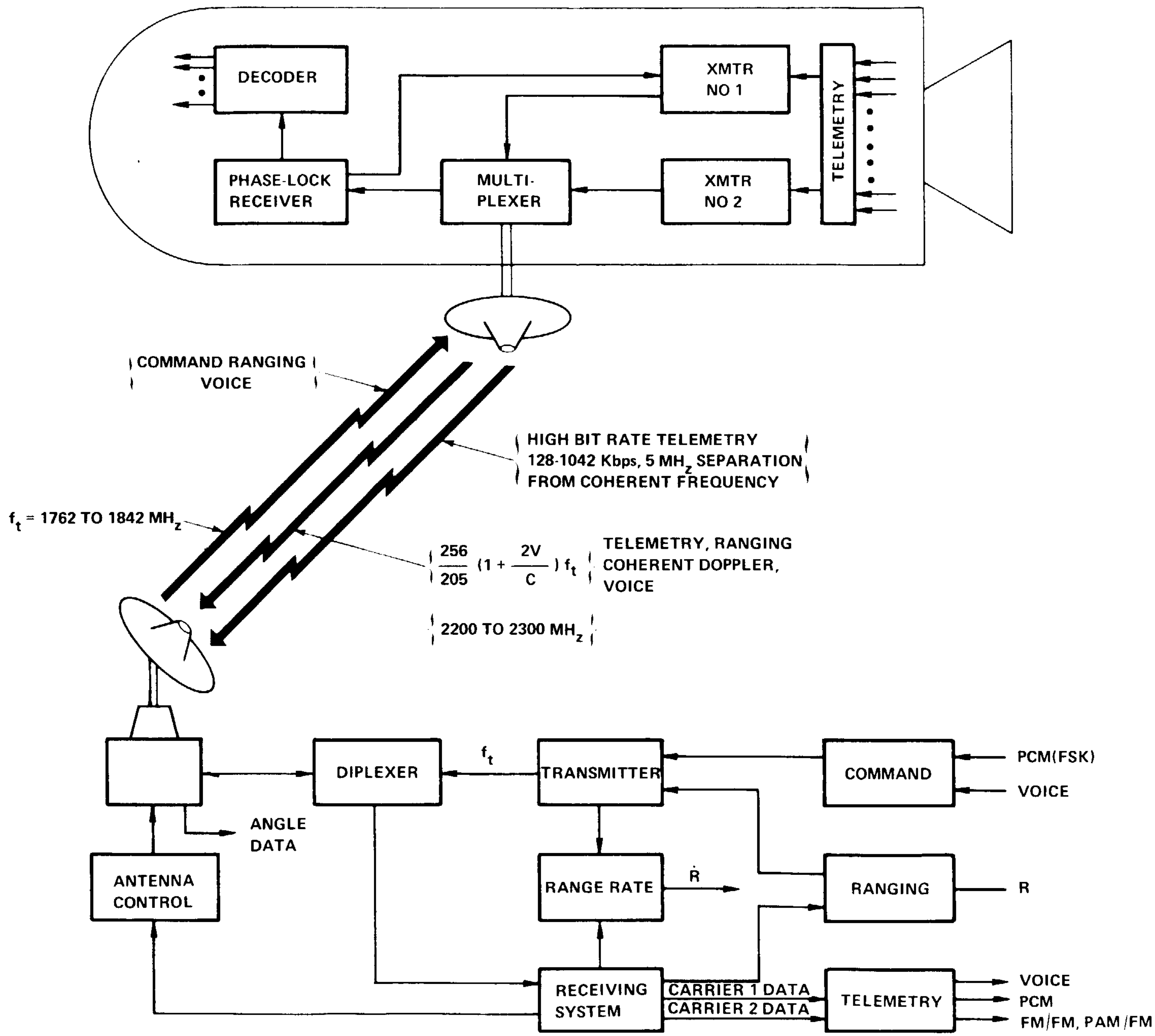

FIGURE 2 - SIMPLIFIED SGLS BLOCK DIAGRAM

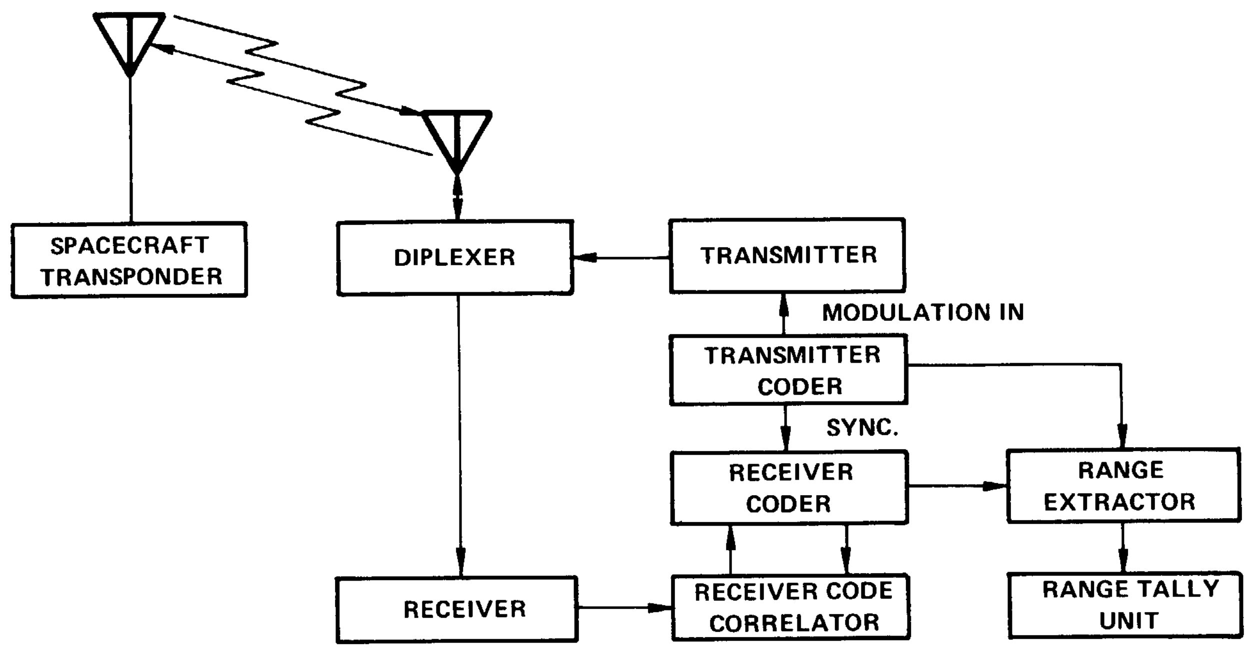

FIGURE 3 - SGLS/USBS RANGING BLOCK DIAGRAM

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